Study of e/γ Trigger for the Electron Calibration Stream

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Abstract

This note describes a study of the possibilities for selecting an electron calibration stream using the High level electron trigger (Level 2 and the event filter). Using the electromagnetic calorimeter reconstruction and the track reconstruction algorithms, an evaluation has been performed of the selection efficiencies and purities for different physics channels with single or double electrons in the final state. A study of the calibration stream composition, including the background from QCD processes, is presented.

1 Introduction

According to the ATLAS Computing Model, we expect to have four event data streams produced from the HLT (high level trigger) system: a physics stream dedicated to the reconstruction of the full ATLAS event sample; an express line stream to rapidly monitor calibration and reconstruction quality on a subset of events before the complete reconstruction is run on the physics stream, and to look for interesting and unusual events; a pathological stream to study events causing problems for the HLT; and finally a calibration stream, processed rapidly and used to obtain the calibration constants for the physics stream reconstruction. The calibration stream will itself be divided into several sub-streams with different types of events. In particular, this study is devoted to the calibration stream for the electrons [1].

Using the High Level Trigger algorithms, described in detail in section 2.1, we have studied the expected rates and purity of the electron stream as a function of the luminosity of the LHC.

2 Tools

In this section all the software tools used are briefly described. All the selection cuts applied and their meanings are defined. Moreover, there is a description of the datasets used in the analysis.

In detail, all the cuts applied for each trigger hypothesis algorithm are summerized in the table 1. The values of the thresholds are those presented in a recent talk on the trigger performance [6].

2.1 Software Tools

The selection at the High Level Trigger (HLT) [2] is seeded by the information obtained at Level 1 (i.e. Regions-of-Interest, RoI). The level 2 trigger reduces drastically the number of events with a relatively small latency, using the information contained in the RoI, while the final trigger level, the event filter, having fewer constraints on the latency, refines the selections using the full event information. After the HLT, we obtain typically "Physics Objects"; these are: muons, electrons, jets. In this case we studied the Trigger Menu for the electron objects, in particular the selection signatures: e25i, selecting single electrons with a threshold of 25 GeV, and 2e15i, for di-electron events containing two electron candidates with at least 15 GeV. The selection criteria for electrons include a shower-shape analysis in the electromagnetic calorimeter, a search for high p_T tracks and a matching between the clusters and the tracks. The selections applied at each trigger level are as follows:

- **Level 1**
  The particles are selected using the Electromagnetic Calorimeter information, applying cuts on the transvere energy (E_T) in the cluster and isolation criteria around the clusters (using both hadronic and electromagnetic calorimeters, with reduced granularity information compared to that available in the HLT). Each RoI is characterised by: $\eta, \phi, E_T^{threshold}$ and isolation criteria.

- **Level 2**
  Starting from the LVL1 region of interest (RoI) of size $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$, the level 2 algorithms refine the selections using the full granularity of the detector. Electrons are selected using both the calorimeter information and tracking information. The shower shapes in the calorimeter and the tracks reconstructed in the inner detector near the calorimeter clusters are

Hypothesis Algorithm	**Cuts Applied (e25i)**	**Cuts Applied (2e15i)**
L2 Calo Hypo	(E3x7/ E7x7) $>$ 0.88 (E1-E2)/ (E1+E2)$>$ 0.64 ET (em)$>$ 22.0 GeV ET (had)$<$ 5.5 GeV	(E3x7/ E7x7)$>$ 0.9 (E1-E2)/ (E1+E2)$>$ 0.72 ET (em)$>$ 11 GeV ET (had)$<$ 1 GeV
L2 Track Hypo	PT$>$ 8 GeV 0$< ET/PT <$ 3.5 $\Delta\eta < 0.08$ match $\Delta\phi < 0.05$ match depending on η	PT$>$ 8 GeV 0.2$< ET/PT <$ 3 $\Delta\eta < 0.07$ match $\Delta\phi < 0.04$ match depending on η
EF Calo Hypo	ET$>$ 23 GeV $\Delta\eta$, $\Delta\phi <$ 0.099	ET$>$ 12.5 GeV $\Delta\eta$, $\Delta\phi <$ 0.2
EF Track Hypo	$N_{SCThits} >$ 2, $N_{blayerhits} > 0$ Impact.Par$<$ 0.5mm	$N_{SCThits} >$ 7 Impact.Par$<$ 1mm
EF Match Hypo	0.86$< ET/PT <$2.29, $\eta <$ 1.37 0.7$< ET/PT <$2.5, $\eta >$1.37 $\Delta\eta$ match$<$0.005, $\Delta\phi$ match$<$0.018	0.7$< ET/PT <$ 1.7, $\eta <$1.37 0.7$< ET/PT <$ 2.5, $\eta >$1.37 $\Delta\eta$ match$<$0.01, $\Delta\phi$ match$<$0.02

Table 1: *Hypothesis Algorithms of the electron trigger chain with the cuts applied at each step of the selection [6].*

analyzed, applying selection cuts on E/p, $\Delta\eta$ and $\Delta\phi$, as described in detail in table 1 (L2 Calo Hypo and L2 Track Hypo algorithms).

- **Event Filter**
  Starting from the Level 2 objects, the Event Filter refines the cuts using more sophisticated algorithms, and access to full event information in the calorimeter and the inner detector. The track search is performed in the SCT and pixel detectors and independently in the TRT. Finally, the objects have to pass three sets of cuts: EF Calo Hypo, EF Track Hypo and EF Match Hypo (checking the E/p and spatial matching between the objects found in the tracking and calorimetry).

2.2 Preselection Cuts for e25i and 2e15i: Definition of Reference Electrons

All the analyses have been performed using the trigger selection hypothesis algorithms corresponding to the HLT trigger chain as described in 2.1, together with with various preselection criteria. These preselection criteria remove events which are not of interest, because they would not pass the level 1 trigger, would not pass offline reconstruction, or because Monte Carlo truth information shows they contain no electrons of interest.

At the end of each job, the TrigSteerMonitor prints a table with the efficiency for each of the algorithms in the sequence. The efficiencies are calculated with respect to reference electrons (as defined in the job options). Typically the efficiency could be calculated with respect to the Monte Carlo electrons, to the LVL1 preselection or to offline reconstructed electrons, either separately or in combination.

Moreover, as described in the section 3.1, a filter selection is applied at event generation level to remove events with no chance of passing the level 1 trigger, and this has to be taken into account when computing the total cross section.

2.2.1 Monte Carlo Preselection Cuts

For the signal samples (single electrons, W and Z decays), additional preselection cuts have been applied on the electrons at the MonteCarlo truth level. These select only electrons that have their momentun in a reasonable interval and that do not cross the crack region. The requirements are:

- one generated electron in each RoI,
- two RoIs per event (only for the Z events),
- Monte Carlo truth $5 < P_T < 100$ GeV
- $|\eta| < 1.45$ and $|\eta| > 1.55$, $|\eta| < 2.45$; these cuts exclude the crack region.

2.2.2 Offline Reconstructed Preselection Cuts

To compare the triggered electrons with the sample that would be reconstructed offline, the offline selection algorithms are also run on all electron candidates. The first two algorithms that are run define as an offline electron any cluster-track match, and then set a series of bits in the IsEM flag variable. For all electron candidates, the candidate has to pass a series of cuts based on the shower shape properties in different compartments of the calorimeter as well as variables combining ID and calorimeter information. If a cut is not passed, then a corresponding veto bit is set in the isEM flag. For candidates with an associated track, identification cuts based on the tracking information have to be passed. Thus if isEM=0, then this is a good electron or photon.

2.2.3 LVL1 Preselection Cuts

The Level1 preselection algorithm simulates the decision of the LVL1 trigger, applying these cuts [3]:

- ClusterThreshold = 19.0 GeV (e25i) or 9.0 GeV (2e15i)
- EmRingIsolation = 3.0 GeV (e25i) or 8.0 GeV (2e15i)
- HadRingIsolation = 2.0 GeV (e25i) or 4.0 GeV (2e15i)
- HadCoreIsolation = 2.0 GeV (e25i) or 4.0 GeV (2e15i)

2.3 Datasets

Several different datasets were used to estimate the composition of the electron stream at low luminosity ($10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$). We took samples generated and simulated for the ATLAS Physics Workshop, in particular:

- Single electrons with $E_T = 25$ GeV, generated with Pythia, about 1000 events (`dataset rome.004022.xxx_Pt_25` Rome Production)

- $Z \rightarrow e^+e^-$ generated with Pythia, about 10000 events
  (dataset rome.004201.recolum01.ZeeJimmy Rome Production)

- $W \rightarrow \nu_e e^-$ generated with Pythia, about 10000 events
  (dataset rome.004203.recolum01.WenuJimmy Rome Production)

- QCD di-jets generated with Pythia, about 138k events. This allows the evaluation of the trigger background
  (dataset rome.004814.recolum01.JF17_pythia_jet_filter Rome Production)
  .

3 Results

In this section the results after the trigger selection are shown. For each sample, the efficiency is calculated at every step of the trigger chain. Both e25i and 2e15i are used. The trigger chains have been run on the ESD samples used previously for the Rome Physics Workshop, the datasets defined in the section 2.3.

The following efficiencies are defined with respect to both offline reconstructed electrons and LVL1 confirmation, as described in detail in section 2.2. The estimation of the rates have been performed for low luminosity, using a MonteCarlo analysis on the CBNT rootples.

3.1 Preselection at Generation Level: Cross Section Used

An estimation of the expected trigger rate and composition of stream is given for low luminosity. We calculated the event rate starting from the cross section (as derived from Pythia) and taking into account the geometrical acceptance of the detector, considering only events that can be reconstructed. In detail, the cross section of production at LHC of the events analyzed are reported in table 2, with the filter efficiency:

- Electrons should have p_T greater than 15 GeV and $|\eta| < 3.0$

- Two such leptons are required for Z events, and one for W events

To calculate the background trigger rates for electrons, we are using the Rome dataset 4814 for dijets with ET(hard) = 15 GeV and a particle level filter cut of $E_T = 17$ GeV. Each dataset contains QCD di-jets as well as physics processes like $W \rightarrow \nu_e e^-$, $Z \rightarrow e^+e^-$ and direct photon production, which have been added to the QCD jets according to their cross sections. The total cross section is reported in table 2.

The rate is calculated using:

$$Rate = \frac{\sigma}{Filter} \frac{N_{sel}}{N_{all}} * L \qquad (1)$$

where the filter takes into account the particle level filter applied at the generation level and reported in table 2, while N_{sel} and N_{all} are the number of events selected by all the trigger chain and the total number of events respectively.

Event	cross section	Filter ϵ	cross section after filter selection
$Z \to e^+e^-$	1603.8 pb	61%	978.3 pb
$W \to \nu_e e^-$	17907 pb	47.9%	8577.5 pb
QCD di-jets	2.3 mb	14.3 %	0.16 mb

Table 2: *The cross-sections for the processes used in this study, together with the acceptance of the particle level filter (geometrical and Monte Carlo truth cuts) and the final cross-sections used for rate calculations.*

Algorithm	Number of Events Single e	Efficiency Single Algo. in %
Initial	932	100
ISEM PRES.	790	84
LVL1 PRES.	784	99
CALO LVL2	772	98
ID LVL2	736	95
CALO EF	706	95
ID EF	698	98
Matching EF	676	96
Cumulative Eff	676/784	84

Table 3: *The values of efficiencies with respect to the reconstructed events and LVL1 confirmation for each algorithm separately. The same trigger chain has been used: e25i. The total number of events are about 1000 single electrons of 25 GeV. The number of events after each preselection algorithm are reported too.*

3.2 Rates for Low Luminosity

The rates below have been computed using the TrigESDAnalysis package to estimate the efficiencies and purities after each trigger algorithm (Athena Release 10.0.1, TrigESDAnalysis-00-00-05 tag), and the MonteCarlo analysis using the CBNT Ntuples. Equation 1 has been used, with $L = 10^{33}\mathrm{cm}^2\mathrm{s}^{-1}$ and the cross sections after the filter shown in table 2.

3.2.1 Single Electron

For reference, we have estimated the trigger efficiency for a sample of single electrons with $E_T = 25$ GeV (e25i chain), with pile-up added.

The efficiency of preselection (including both LVL1 confirmation and offline reconstruction isEM) for this sample is about 84%. Table 3 reports the efficiencies of each algorithm with respect the previous one. These efficiencies are not cumulative.

Figure 1 shows the p_T and energy distributions after the preselection cut isEM.

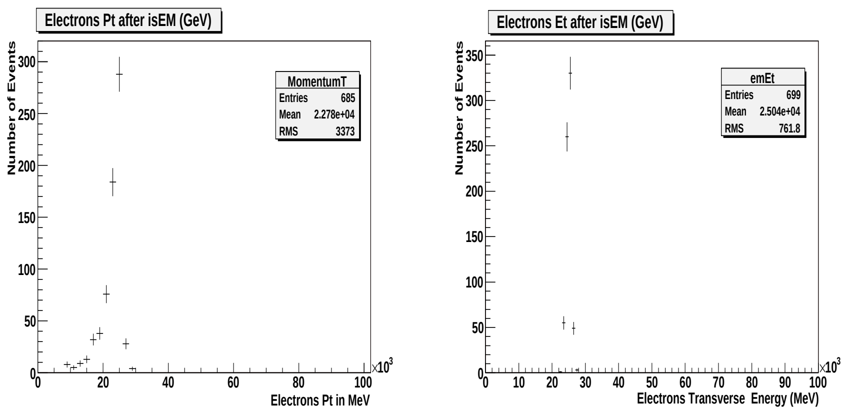


Figure 1: *Electron p_T measured in the tracking (left) and energy (E_T) in the calorimeter (right), after the isEM preselection cuts applied, for the $E_T = 25$ GeV single electron sample.*

3.2.2 $W \to e\nu_e$

The sample W is selected applying the trigger chain: e25i. The electrons in the crack region have been excluded and only one electron in each electromagnetic cluster is required too (Number of primary electrons equal to one). The isEM flag and the LVL1 confirmation are then applied as preselection to define the right sample of reference electrons. Table 4 shows the results for the W sample, compared with the efficiencies derived from the 25 GeV single electron sample. The efficiencies are cumulative, and calculated with respect to the electrons obtained after the preselection cuts.

The estimated rate after all selections, using the formula 1 and the cross section reported in table 2, is about 9.1 Hz at a luminosity of $L = 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

In figure 2, the p_T distributions of the electrons from W decay after the preselection and the complete e25i trigger chain are shown.

The comparison between the electromagnetic energy transverse for the single electrons and the electrons from W decay is shown in the plot 4, this explains the different efficiency obtained for the T2CaloHypo algorithm for these events. The efficiency as a function of p_T of the electrons from W decay is shown in figure 5.

The η distributions for single electrons after the Monte Carlo preselections are shown in figure 5.

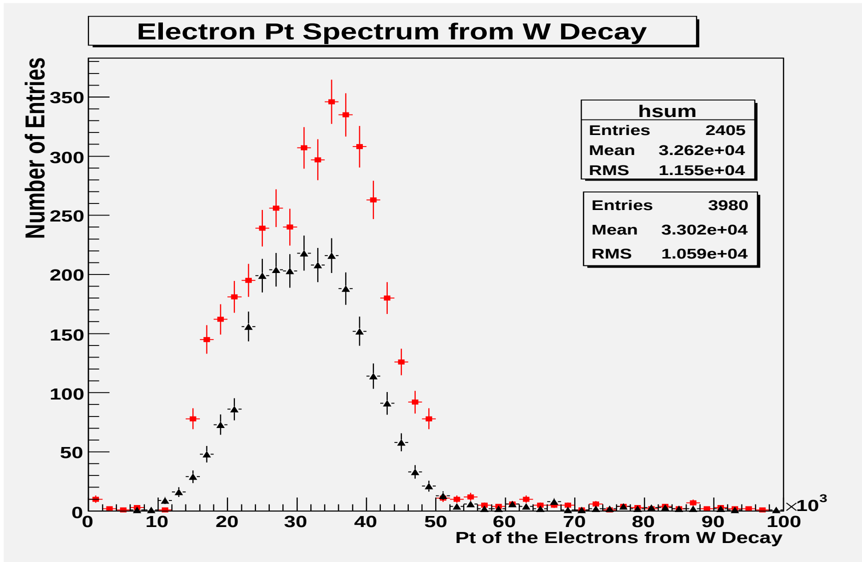


Figure 2: *Electrons P_T spectrum of events $W \rightarrow \nu_e e^-$. In black triangles there is the electrons P_T spectrum of events after all the trigger chain e25i reconstructed in the tracker, in red squares the distribution obtained after the preselection cuts and before the selection of the e25i chain, these are the "reference events".*

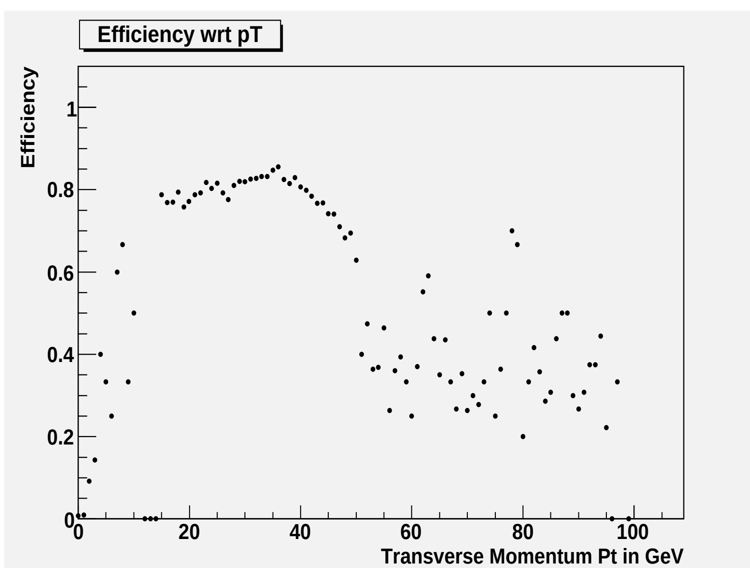


Figure 3: *Efficiency with respect to the transverse momentum of the electrons from events $W \rightarrow \nu_e e^-$. The efficiency is calculated per bin (1GeV), as the ratio of the MonteCarlo p_T spectrum before and after all the cuts.*

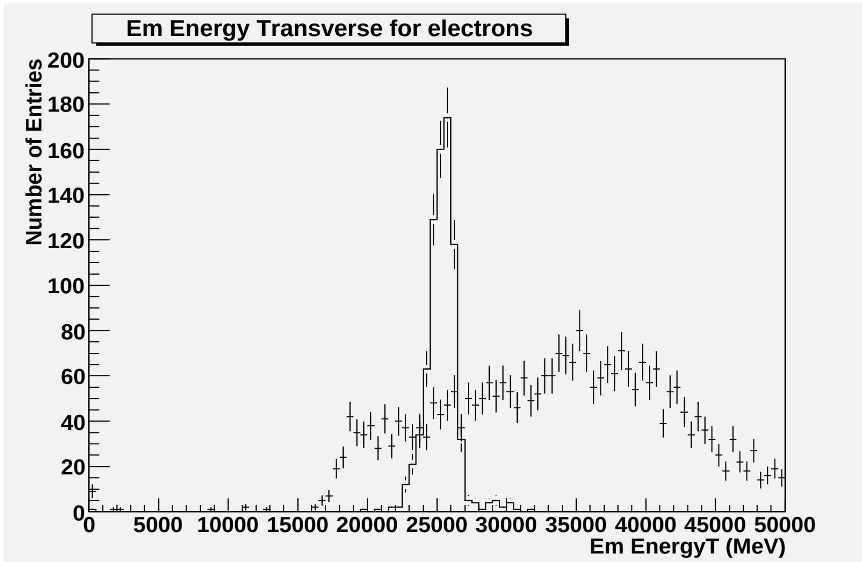
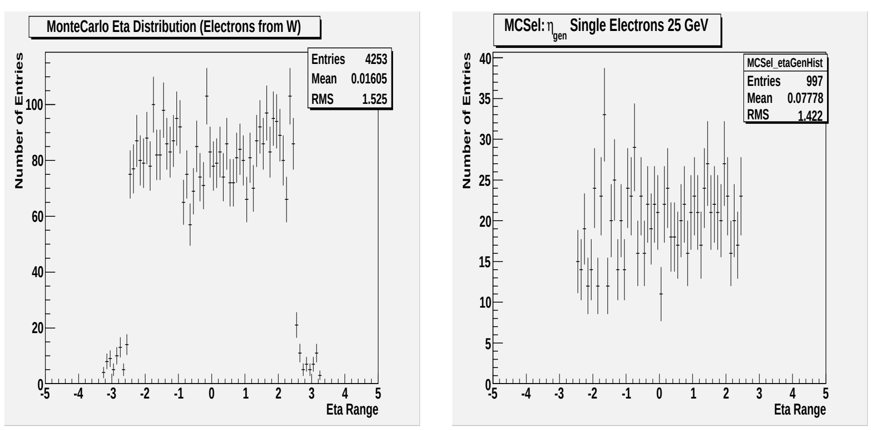


Figure 4: *Transverse electromagnetic energy spectrum from $W \rightarrow \nu_e e^-$ events (points) and single electrons (histo). The threshold defined in the e25i trigger chain is $EmE_T > 22GeV$, this explains the different algorithm efficiency between single electrons and W events.*



(a) (b)

Figure 5: *The (a) plot shows the the electrons η distribution from MonteCarlo informations (with the constraint of RoI) for the sample: $W \rightarrow \nu_e e^-$ while the (b) plot the same distribution but for the single electrons of 25 GeV.*

3.2.3 $Z \rightarrow e^+e^-$

The Z sample is selected applying two independent trigger chains: e25i and 2e15i. In both cases the electrons in the crack region have been excluded and only one electron in each electromagnetic cluster is required (Number of primary electrons equal to one). The Monte Carlo preselection cuts have

Algorithm	Number of W events	Efficiency W in %	Efficiency Single e in %
Initial	10036	100	100
ISEM PRES.	5329	53	84
LVL1 PRES.	5101	51	84
CALO LVL2	4470	88	98
ID LVL2	4156	81	94
CALO EF	3944	77	90
ID EF	3904	76	89
Matching EF	3768	74	86

Table 4: *The values of efficiencies with respect to the reconstructed events (after LVL preselection) for all the algorithms (ID and Calo) for the level 2 and the event filter. The cumulative efficiencies of* $W \rightarrow \nu_e e^-$ *and* $E_T = 25$ *GeV single electron samples are compared, for the e25i trigger chain.*

been applied before the trigger chains, see section 2.2.1. The trigger steering uses two independent selection chains, and the number of selected events is the algebraic union of the events selected by the two chains. In the table 5, all the efficiencies are reported for each algorithm, and finally the total efficiency of selection obtained by the sum of the e25i and 2e15i trigger chains. For each algorithm is reported the number of selected events, an event is defined "selected" with respect to the 2e15i chain when there are two electrons per event while for the e25i chain when there are one or two electrons per event.

The estimated rate using the formula 1 and the cross section after filter reported in table 2, is about 0.84 Hz. The combined efficiency is obtained taking the events that are selected by e25i or 2e15i trigger chain and excluding double counting from events selected by both. It is interesting to note that nearly all Z events are selected by the e25i trigger chain alone. The small fraction of electron momenta betwen 15 and 25 GeV and the lower efficiency for selecting two electrons as compared to one mean that the 2e15i trigger adds only a small number of events not selected by e25i, and 2e15i alone has a significantly lower efficiency for the overall sample.

3.2.4 QCD Di-jets

The selection of QCD events is done using the same hypothesis algorithms as for the signal samples, but without the requirement on the number of primary electrons in each cluster. The electron candidates in this sample represent the background in the calibration stream with respect the other physics events described above. Each dataset contains QCD di-jets as well as physics processes like $W \rightarrow \nu_e e^-$, $Z \rightarrow e^+e^-$, and direct photon production, so we analyzed in detail the Monte Carlo composition of the stream to define what we obtain after the selection of the relevant physics processes. Applying the cuts described above the expected rate is about 20 Hz, with an efficiency of 2.9 % with respect to the preselection and an efficiency of preselection of about 0.004 %.

The total number of analysed events total events is about 140000, and only 16 events survive all the trigger cuts, with the following composition:

- Genuine electrons from W and Z or B hadron decays about 50%
- Converted photons from π or jets about 31%

Algorithm	Number of Events	Number of Events
	e25i	**2e15i**
PRES.	5694	5659
CALO LVL2	5543	4969
ID LVL2	5304	4969
CALO EF	5160	4940
ID EF	4993	4288
Matching EF	4955	4003
Efficiency	87.6%	70.3%
Combined Eff.	88%	

Table 5: *The number of* $\mathrm{Z} \rightarrow \mathrm{e}^{+}\mathrm{e}^{-}$ *events for each single algorithm of the trigger chains: 2e15i and e25i, and their matching. The last rows show the efficiency for each trigger chain and their combination, the number of events of the match is calculated summing the events accepted by a trigger chain plus the events of the other chain not yet included. Almost all of the events are triggered by e25i trigger chain.*

Algorithm (e25i)	Number of Events	Rate (Hz)
Initial	138532	—
PRES.	551	640
CALO LVL2	170	198
ID LVL2	33	38
CALO EF	25	29
ID EF	25	29
Matching EF	16	19

Table 6: *The number of events for each single algorithm of the trigger chain 25ei, and their matching for QCD-jets events.*

- Fake events, for example charge particles with tracks randomly associated to electromagnetic calorimeter clusters, about 19%

The selected events in the background sample that contain genuine electrons can be considered as useful for the electron calibration stream as well.

Figure 7 shows the rate of accepted events as a function of the energy of the triggered electron candidate from the Calorimeter EF algorithm. Although the overall statistics are very low, it can be seen that the electrons from W and Z boson decays have a somewhat softer E_T spectrum than those from the QCD background.

4 Different Selections

In this section we studied applying different cuts at the event filter to reduce the total electron stream trigger rate to 10 Hz, keeping as large a fraction as possible of the pure electrons. The cuts applied at

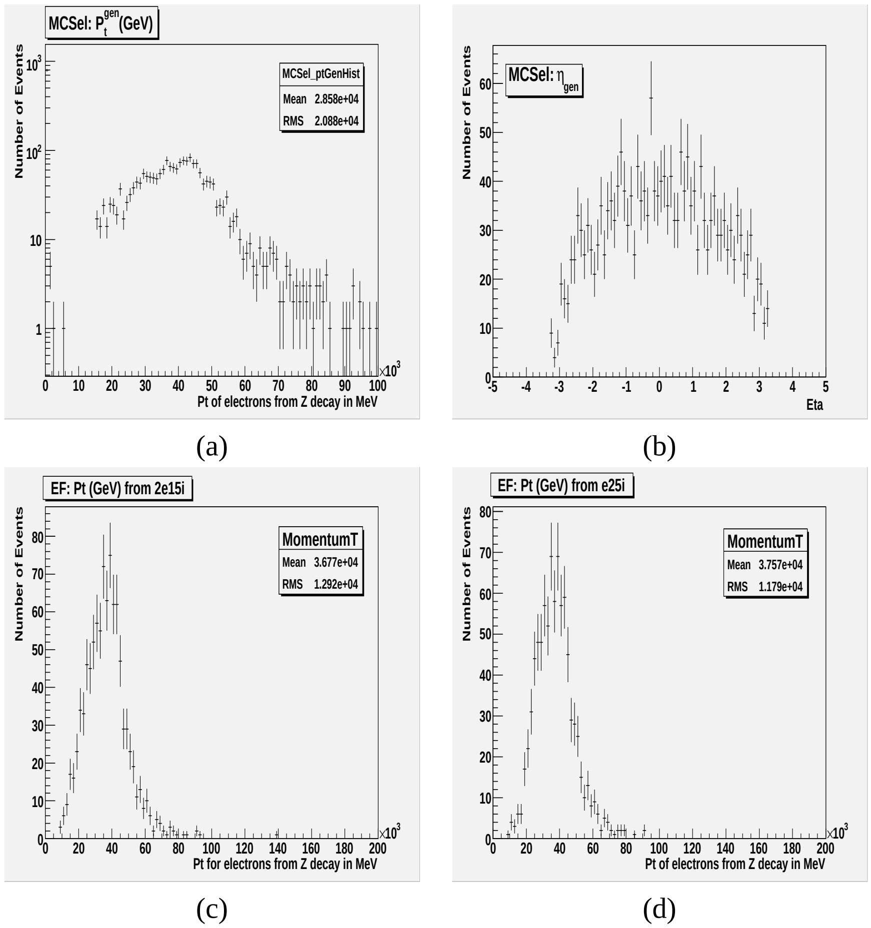


Figure 6: $\mathrm{Z} \to \mathrm{e}^+\mathrm{e}^-$ *sample. The (a) plot shows the electron p_T from MonteCarlo information (with the constraint of RoI), while the (b) plot shows the eta distribution of the electrons from Z decay. The electron p_T distributions, after the trigger chains: 2e15i and e25i, are reported in the plots (c) and (d) respectively.*

the calorimeter filter level are not yet optimized, and possible improvements can be achieved modifying the thresholds applied to the E/p ratio and track parameters. Figure 8 shows the E/p variable for W signal and QCD background events in different η ranges. Again, although the statistics for the background sample are very low, it looks possible to increase the signal purity by tightening the upper cut on E/p.

In table 7, the effect of applying two different sets of cuts is shown on the rate of W and Z events in comparison with the rate of QCD jets. Moreover for the QCD jets, the rate composition has been analysed and the genuine electron component calculated.

Taking into account the last cuts, we can obtain about more than 17 Hz (Z+W+jet) trigger rate, where about 15 Hz are genuine electrons useful for the electron calibration stream. The Z events are less than 1 Hz after the cuts.

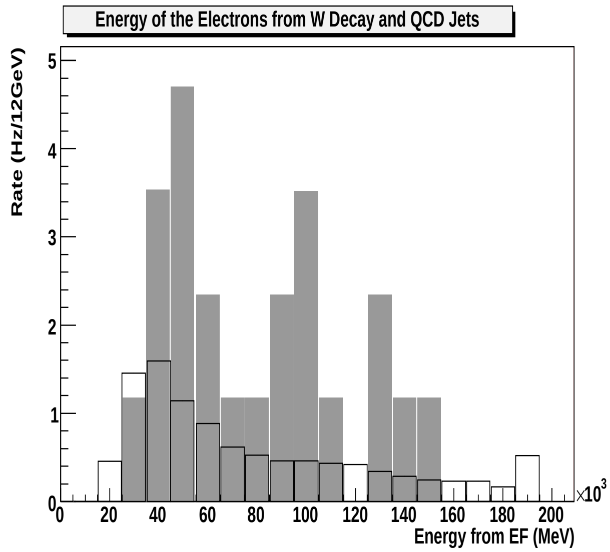


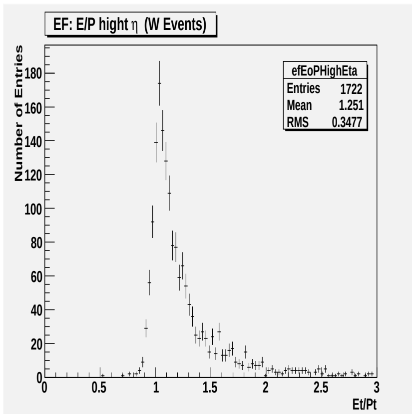
Figure 7: *The plot shows the rates as function of electron energy after EF. The rates have been obtained normalized the number of the entries with respect to the rate with 12 GeV per bin. The QCD events are the dark histogram, the electrons are represented by the open histogram.*

5 Conclusions and outlook

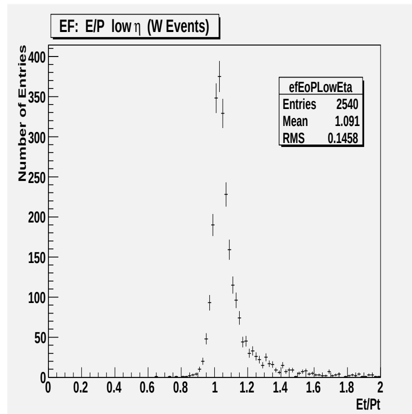
After this first analysis on the Rome data sample using the Electron High Level Trigger chains (e25i and 2e15i) we have estimated the electron trigger rate expected at low luminosity. The efficiency and the purity have been calculated, with the standard thresholds and with modified cuts on the Event Filter, to optimize as much as possible the ratio purity over efficiency of the obtained sample. After some limited optimisation, a total rate of 17 Hz has been found, dominated by genuine electrons from W and Z decay.

For the background, the number of selected events is very small, due to the limited size of the available background sample. This makes it impossible to study further cut optimisation to reduce the rate to the target of 10 Hz. However, it is already apparent that simply increasing the E_T threshold, while reducing the rate, will not increase the purity of the selected sample. Much more background event statistics will be required to better understand the relations between the background composition and the cuts on the E/p ratio.

More analysis will be performed on the CSC samples. In addition to looking at the e25i trigger, it will be of interest to look at lower thresholds for lower luminosity running (e.g. 10^{31} and $10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$). This is not possible with the present background sample due to the filter cuts imposed in the event generation.



(a)



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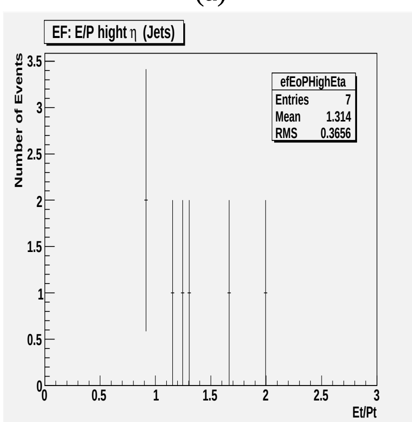
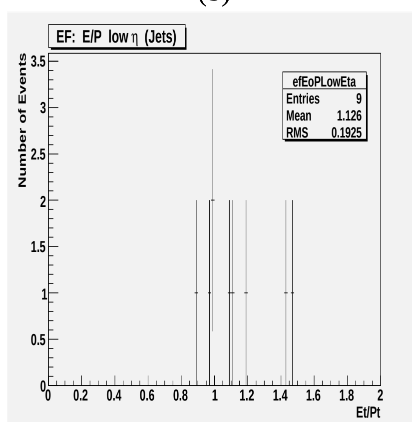


(c)



(d)

Figure 8: *In the (a) plot, the E/p ratio for the W events for high η is shown, while in the (b) side the same E/p ratio for W but for the low η cuts. In the (c) and (d) plots the same variables but for the electrons in QCD jets for high and low eta range.*

EF Match Cuts	W Event Rate	QCD Jets Rate	Z Rate	Total Rate
0.86$< ET/PT <$2.29, $\eta > 1.37$ 0.7$< ET/PT <$2.5, $\eta <$1.37	9.1Hz	19Hz(9.5Hz)	0.84Hz	28.9Hz(19.4Hz)
0.86$< ET/PT <$1.65, $\eta > 1.37$ 0.7$< ET/PT <$1.4, $\eta <$1.37	8.5 Hz	13Hz(7.6Hz)	0.88Hz	22.4Hz(17.0Hz)
0.86$< ET/PT <$1.65, $\eta >$1.37 0.97$< ET/PT <$1.15, $\eta < 1.37$	7.3Hz	9Hz (6.8Hz)	0.87Hz	17.2Hz(15.0Hz)

Table 7: *New cuts applied at Event Filter level to reduce the total rate to about 15 Hz. In the QCD column, in parenthesis, the rate of genuine electrons is reported. The Z rate is almost the same, the different cuts are applied only on the e25i chain then the matching of the two independent trigger chains reproduces the same rate.*

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